EVOLUTION OF ARTIFICIAL NEURAL NETWORK ALONG WITH COMPARATIVE STUDY AND ITS' CHALLENGES

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Abstract- A neural network has a complex structure. It consists of a group of interconnected neurons. An artificial neural network term is evolved from biological neuron. Biological neuron processes information in brain. For solving complex problems, Artificial Neural network (ANN) plays an important role. We can apply ANN techniques in pattern recognition, prediction, function approximation, call control, scrolling web pages just by left- and right-hand gestures. Outline of artificial neural network and working of it is presented. It maps neural learning process with ANN. It elaborates the architectures and learning rules. It also presents limitations, advantages and the area which has not been covered using these techniques are referred as a future work.

IndexTerms **- Biological Neuron, Artificial Neuron, Artificial Neural Network (ANN), Supervised Learning, Unsupervised Learning, Feed forward Network, Feedback Network, Short Term Memory (STM), Long Term Memory (LTM)**

I. INTRODUCTION

The concept of artificial neural network is evolved from subject biology. Biological neuron plays an important role in human body. Neural network is a web of millions of neurons. With the help of them parallel handling is done. Parallel processing is an excellent feature of neural network. A neuron is a natural cell in human body. It has soma or cell body, nucleus, dendrites, axon etc. Axons of one neuron carries electrical signal to another neuron for processing. The activation of neuron is transformed through different signal functions. Basically, ANN is characterized by three types of parameters based on interconnection property, application function and learning rule. Interconnections among neuron may be in feed forward or feedback network form. Application function can be classification, association, optimization and self-organizing model. Learning rule can be supervised or unsupervised in nature. This paper introduces neuron as a real and artificial which subsequently introduces the term ANN. Different signal functions which generate output signal depending on activation are shown with the help of diagrams. It also explains the architecture of ANN and contrast between supervised and unsupervised learning. Now a days ANN technique becomes necessary to development in the field of new technology.

II. EVOLUTION OF NEURAL NETWORK

The evolution of thought process, the structure and the function of the human brain and its' relationship with behaviour had a big history. Today in neuroscience, there is vast progress. The Greek philosopher Aristotle and Plato has co-related the structure of the human brain with its' function and behaviour of the human. Aristotle believed that the heart was the seat of sensation. In contrast, Plato hypothesized that the brain was the seat of soul and also centre of all control. The Hippocratic school of thought also supported by anatomical studies that "from the brain only arise our pleasure, joys, sorrow, pains and tears etc." They also stated that brain was the seat of all intelligence. Vartanian highlighted these thoughts and associated the term cerebrum with sensation and cerebellum with control. According to Leonardo da Vinci, science comes by observation not by authority. For deep study he performed dissection of the human body. French physiologist Marie-Jean-Pierre Flourens established a link between cerebrum and co-ordination of movement and also with cerebrum and sensation. Cajal is known as father of modern brain science. He defined the term neuron as information processing cell of the brain. Synapses the point at with neurons communicate with each other. The human brain has a complex structure. It has cerebrum (large brain), cerebellum (small brain) and neocortex (layer of cells i. e. convoluted sheet). Approximate brain weight is 1400 gm. Fig. 1 shows Biological neuron structure.

A. Biological Neuron:

- Each neuron has soma or cell body containing nucleus and organelles
- A tree like structure, known as set of dendrites receives input electrical signals
- A tubular extension from the cell soma known as axon carries an electrical signal from soma to another neuron for processing
- Each neuron has only one axon which terminate on the dendrites of other cells

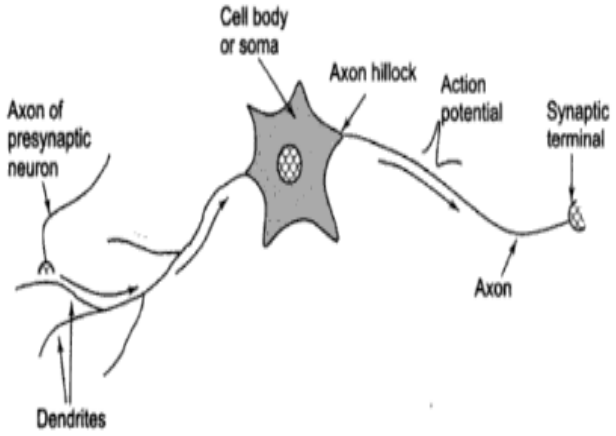

fig. 1 A Biological Neuron (Satish Kumar, 2014)

B. Working of Real Neuron into simple mathematical neuron model

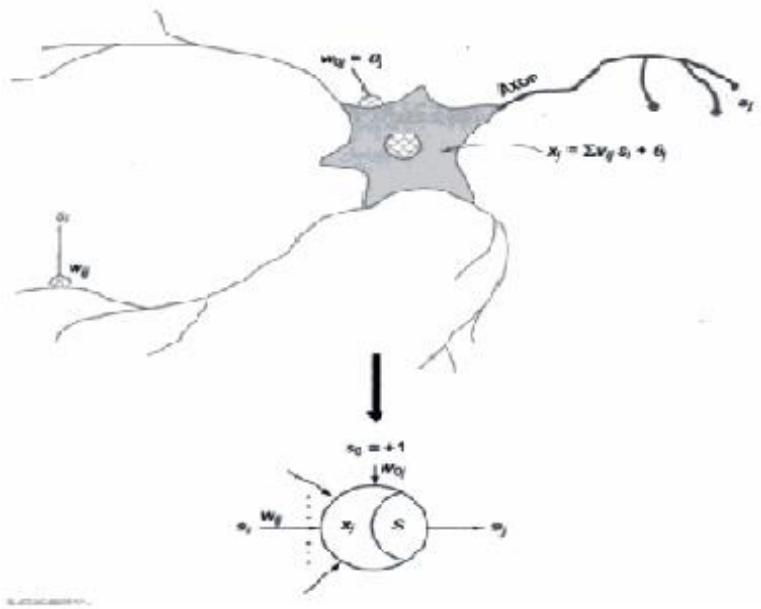

fig.2 Artificial Neuron Model (Satish Kumar, 2014)

Fig. 2 shows j^{th} artificial neuron. It receives input signal s_i from n different sources. They traverses weighted pathways w_{ij} which represents weight from neuron i to neuron j. Internal activation X_j is generated which is a weighted aggregation of the impinging signals modified by internal threshold θ_j.

$$Xj = \sum_{i=1}^{n} w_{ij+} \theta_j \qquad \text{Eq.1}$$

The threshold θ_j represents the internal firing threshold of real neuron. The activation of the neuron transformed through signal functions to generate output signal (Satish Kumar, 2014).

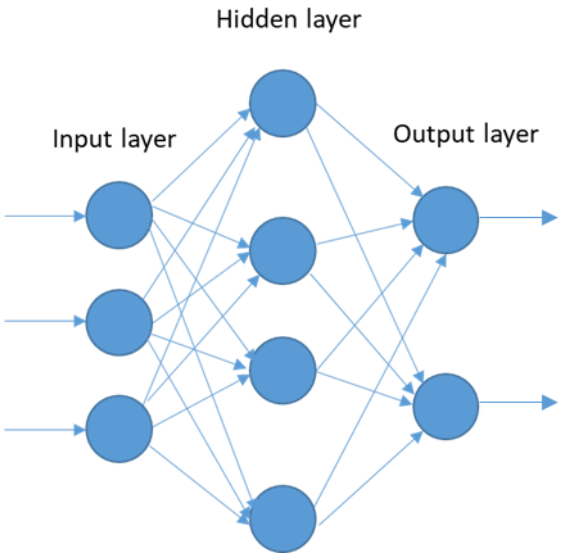

fig.3 Multi-layered Artificial Neural Network

The term artificial neural network interconnects neurons of the different layers. Fig.3 shows three layers. Input layer contains three input neurons These neurons send data to the second layer i.e. hidden layer which has four neurons. There is no restriction upon the number of hidden layers. Hidden layer send data to output layer. Two neurons are shown in output layer. More complex system has more layers.

Neural network consist of eight components :

1.Neuron: three types input, hidden and output neuron

2. Activation state vector

3.Signal Functions

4. Pattern of connectivity

5 Activity Aggregation Rule

6. Activation Rule

7. Learning Rule

8. Environment

III. NEURON SIGNAL FUNCTIONS

1.**Binary Threshold Signal Functions**: Neurons represented as binary signal function are known as binary neurons or threshold logic neuron (TLN).

It generates 0 or +1 signal

$$S.(x_j) = \begin{cases} \mathbf{1} & \mathbf{x_j >= 0} \\ \mathbf{0} & \mathbf{x_j < 0} \end{cases} \qquad \text{Eq.2}$$

Fig.4 shows +1 signal value for net positive activations and 0 signal value for net negative activations. It has only two states, i.e. sj = S(xj) ∈ {0,1}.

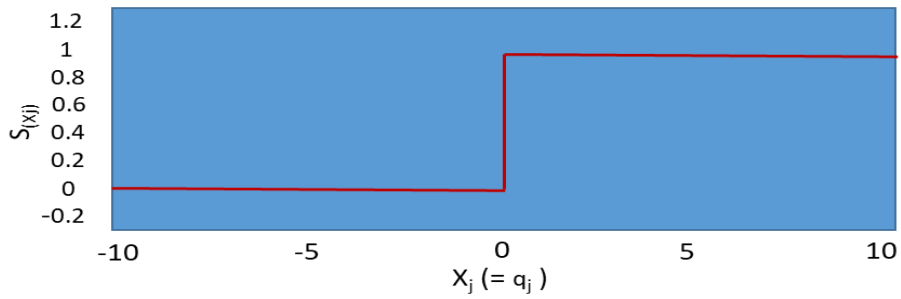

fig.4 Binary threshold Function: θj = 0

2. **Linear Threshold (Ramp) Signal Function**: This is the simplest signal function. Here signal is equal to activation.Linear threshold function is bounded version of linear signal function.Fig.5 shows the slope parameter αj = 1 / xm. Here, xm = 2 and αj = 0.5, i.e. 1/ xm = ½ = 0. 5.

$$S.(x_j) = x_j \qquad \text{Eq.3}$$

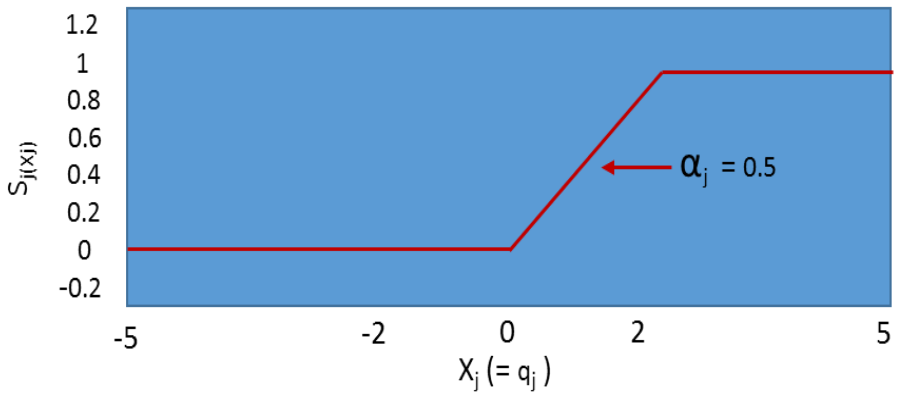

fig.5 Linear threshold Function: θj = 0

3. **Sigmoidal (Logistic) Signal Function**: This function uses more frequently in neural networks. Monotonocity and continuity are very useful mathematical properties of it..There are no breaks, shows the term continuity . As the x increases, functions y will always increase or decrease. It is represented by,

$$S_i.(x_i) = \frac{1}{1 + e^{-\lambda j x j}} \qquad \text{Eq.4}$$

Where λj – gain scale factor

fig.6 shows λj → ∞ , logistic signal function is smooth and it approaches to non-smooth binary threshold function. Here 0.5 is the signal crossing point

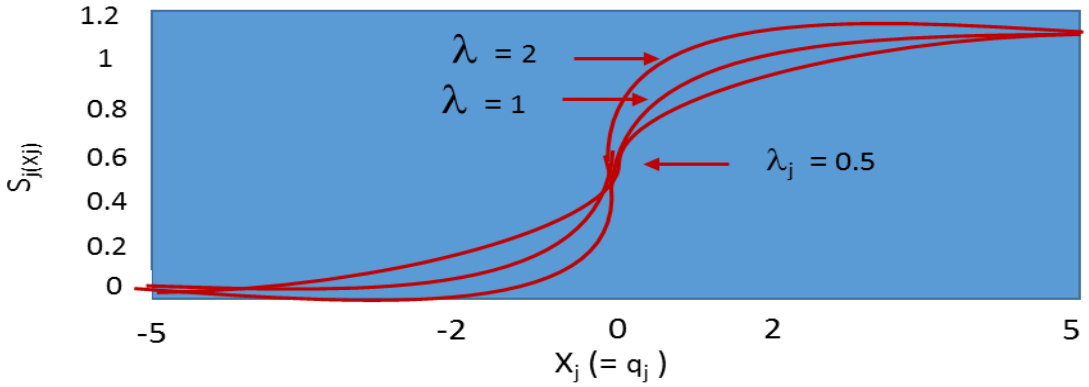

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fig.6 Sigmoidal Signal Function: θj = 0

4. **Gaussian (Bell shaped) Signal Function**: This is the powerful signal function. Spread factor spreads or diffuse function according to value. In fig.7 it is shown that the function becomes more sharper or diffuse by variation in the spread factor. Strong signal responses are close to the center and weak responses are far away from the center. It takes input from (-∞, ∞) and smootly reaches to (0, 1).

$$S_j.(x_j) = \exp\left[-\frac{(x_j - c_j)^2}{2\sigma_j^2} \right] \qquad \text{Eq.5}$$

Where, σ_j – Spread factor

c_j - center

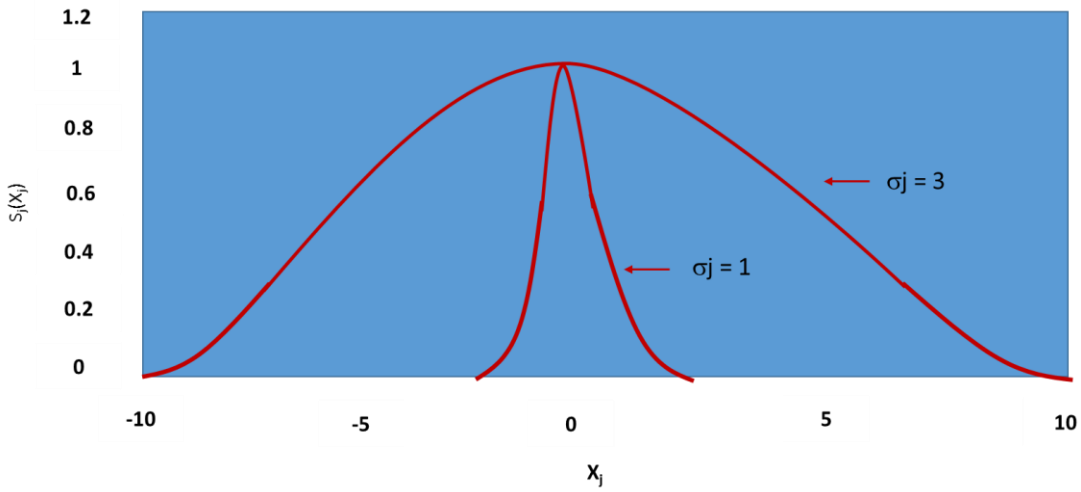

fig.7 Gaussian Signal Function: center = 0

5**. Stochastic / Noisy / Probabilistic / Non-deterministic Neurons**: There is randomness. According to probabilistic rule signal state Sj switches of neuron j.

$$Sj = \begin{cases} +1 \text{ with probability } P(xj) \\ -1 \text{ with probability } 1 - P(xj) \end{cases} \qquad \text{Eq.6}$$

IV. ARCHITECTURE OF NEURAL NETWORK

A neural network N can be viewed as directed graph. In this artificial neuron means nodes and directed weighted edges represent connection between neurons. Input is presented to the input layer. Outputs are generated as signals of the output layer. The signals pass through one or more intermediate or hidden layers depending upon signal function. Neurons can be connected in basic two ways.

1**. A feed forward architecture**: In this type network has no loops.

2**. A feedback (recurrent) architecture**: In this type network has loops due to feedback connections.

1. Feed forward Hetroassociator:

Association of vectors from one space to vector of another space in multilayer network are called hetroassociator.

Mathematically it is represented by,

$F: R^n \text{ ----> } R^p$

As shown in fig.8 (a), the neural network N takes a vector in R^n and maps it to a point in R^p.

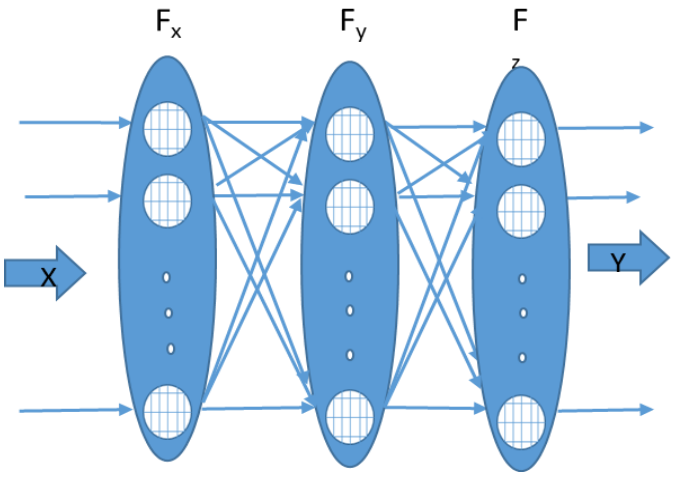

fig.8 (a) Feed forward Hetroassociator

2 a. Feedback Autoassociator:

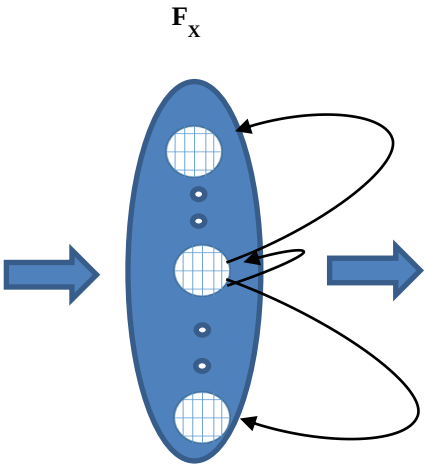

fig.8 (b) Feedback Autoassociator

In autoassociator, neurons in a single field connects back onto themselves then that network is called autoassociator. As shown in Fig.8(b). It associates single pattern in R^n with itself.

Mathematically it is represented by,

$$F: R^n \text{----}> R^n$$

2 b. Feedback Hetroassociator: There is loop in the network, as they take feedback. Fig 8 (c) represents how the new input pattern is presented and output is generated. These new outputs are fed back as input to the system and modified ouputs are generated.

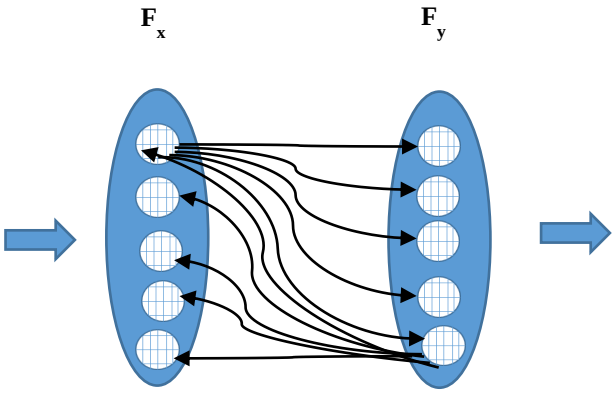

fig.8 (c) Feedback Hetroassociator

V. COMPARATIVE STUDY

Table 1 : Comparison of Supervised and Un-supervised Learning

Sr.No.	Supervised Learning	Unsupervised Learning
1.	Inputs and outputs are provided	Input is provided but not with desired output. Without outside help network has to make sense of the input.
2.	Uses pattern class information of each training pattern	Adaptively clusters patterns to generate decision without prior information
3.	Priori information of class is present	No priori information of class
4.	It is classifier	It approximates information
5.	Learning is generally off-line	It allows to learn in real time
6.	Global error signals govern learning	Local information is used for learning
7.	Internal parameters adapt using error correction or gradient descent learning procedure	Differential equation defines the learning process

Table 1 differentiates between supervised learning and un-supervised learning. It considers the input, output, class, clusters, learning type, global error to contradict between them.

VI. RELATED WORK

Explanation of neural network in human body is presented. The best example of parallel processing is human body. Diagram of biological neuron is elaborated. Its' parts like soma, nucleus, axon, dendrites, synapses etc. are defined. Structure of artificial neuron is shown. There can be more than one layer i.e. Multi-layered artificial neural network. In this there are input layer, hidden layer and output layer. There can be more than one hidden layer. What is artificial neuron? What is the mathematical function of it? It is presented. The excellent characteristics of brain of human being which are not present in modern computer i.e. learning ability, distributed memory, fault tolerance, network structure, parallel processing, collective solution etc. are explained in brief (Vidhushi Sharma et al. 2012). Network structure has two basic types i.e. feed forward (non-recurrent or associative) and feedback (Recurrent or Auto associative) network. These architectures have been explained diagrammatically. Activation function transfers output from an artificial network to another artificial network. There are four types of it i.e. binary threshold, piecewise linear (ramp), sigmoidal (logistic), Gaussian (bell shaped) signal functions. It is represented graphically. It concludes with various applications and limitations of Neural network. Now a day, as the technology is developed, it becomes necessary to increase artificial intelligence techniques. Parallel processing is the focused area as it saves time and money.

The trained neural network which can be considered as an expert for analysing of information. Adaptive learning, self-organization, real time operation, fault tolerance are the main advantages of neural network. Conventional computer uses algorithmic approach i.e. follows set of instructions to solve problem. It uses cognitive approach also to solve a problem. The way to solve problem must be known in unambiguous way. In contrast to that neural network works similar to human brain. It uses parallel processing. It learns by example. They cannot be programmed to perform specific task (Ms.Sonali B. Maind & Ms Priyanka Wankar, 2014). It finds how to solve problem by itself. Result can be unpredictable, if network functions incorrectly. It adopts the terms behave, react, self-organize, learn, generalize and forget. This paper presents different applications and advantages of neural network. It also explains the simple neural network, working of it. How different neurons can be clustered together? How the information processes in dynamic interactive and self-organizing way? This is elaborated with help of diagram. Supervised and unsupervised training approaches are discussed. Unsupervised or adaptive training is the promising area. One application is military action is discussed. Due to new combat techniques and weapons it is a big challenge.

Basic study of Neural Network with the help of biological or genetic neuron is presented. It associates the work of biological neuron with artificial neuron. ANN represents interconnection between different neuron from different layers (Er. Parveen Kumar & Er. PoojaSharma, 2014). Input, Hidden and Output layers are represented with input patterns x_1, $x_2 \ldots x_n$ and weights $w_{k1} \ldots w_{kn}$, bias b_k, Activation function and output y_k. Characteristics of Neural network are shown in diagram. Feed forward and feedback network is represented through diagram. Ability of parallel processing, distributed memory, fault tolerance, collective solution and learning is explained. Advantages, limitations and applications are discussed. It concludes with need of parallel processing.

ANN focusses on pattern classification because of structured design and learning methods It performs classification tasks efficiently. There are different algorithms and each algorithm having their different learning ability and inference accordingly. ANN learning paradigms are classified as supervised, unsupervised, reinforcement and stochastic learning (R. Sathya & Annamma Abraham, 2013). In supervised learning there is availability of teacher or supervisor. Teacher classifies training examples into classes. Unsupervised training identifies pattern class information heuristically. Reinforcement learning learns through trial and error interactions with its environment Supervised learning adjusts interconnection weight to learn. Unsupervised learning uses information associated with group of neurons. Reinforcement learning uses function to modify local weight. Adjust on free parameters of network are helpful for differentiating learning as supervised, unsupervised models. There are different learning rules. I supervised learning data source with correct classification is already assigned. It is utilized in feed forward and multilayer perceptron model (MLP). Learning through training is Error back-propagation algorithm it occurs in two passed i.e. forward and backward pass. Supervised learning finds solution for linear and non-liner problems e.g. classification, forecasting, prediction etc. unsupervised learning learns by self-organizing weights. It identifies hidden pattern in unlabeled input data. No direction and no prior information is provided. Self-organizing maps looks back for patterns those which have not been considered previously. It has three phases competition, co-operative and adaptive phase.

Demonstrated the necessity of neural networks in todays artificial knowledge in advancement of intellegent framework. Parallel processing i.e. multitasking is an excellent feature of human being (Md. Tanjil Sarkar et al. 2017). Characteristics like adaptive learning, self-organization, real time operation, fault tolerance are helpful in ANN. A trained neural network can be considered as 'an expert' for analysing information. It also introduces neuron and multilayer artificial neural network with its excellent characteristic. Need of ANN is elaborated. Modern computer and biological neural system are differentiated. Characteristics are explained diagrammatically. Different activation function transfers output from one neuron and send signal to another neuron. Taxonomy of network architecture is shown. It explains the concept of supervised and unsupervised training in detail. It concludes with different applications, advantages and limitations of neural network.

VII. ADVANTAGES

1. Adaptive Learning
2. Self-Organization
3. Real time operation
4. Pattern recognition
5. System development through learning instead of programming
6. In changing environment, NN are flexible
7. Complex interactions can be handled by NN. It also model data easily as compared to traditional approaches

VIII. LIMITATIONS

1. In day to day life it is not general-purpose problem solver
2. No structured methodology
3. No single standardized paradigm
4. May generate unpredictable output
5. Black box nature. As it does not describe how to solve problem

IX. APPLICATIONS

1. Answer an incoming call with swipe of the hand to speaker ON while driving i.e. Control of call

2. Classification, Pattern Recognition, sequential decision making

3. Scroll web pages with simple left- and right-hand gestures

4. Face recognition, speech recognition, hand written text recognition, medical diagnosis

5. When hands are wet, touch-free controls are beneficial

6. Airline security control

7. Prediction of stock price index

8. Smart phone can dock the device to the T.V.

X. CONCLUSION

Neural network has a very bright future. Indeed, it is the key in the field of new technology. There is need to improve the ANN performance. There are various advantages of ANN over conventional systems. ANN can capture any relationship quickly and model phenomena accordingly. Otherwise it would be very difficult task.

XI. FUTURE WORK

If ANN concept is combined with fuzzy logic and computational automata, it will overcome the limitation of it. Unsupervised learning is the promising area it enables type of robots to continuous self-learning as they encounter new situation and new environment where exact training set do not exist. Need to implement neuro fuzzy systems.

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